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Report of UK-China workshops on the **Future of energy storage:** technologies and policy

中英工作组报告 **未来储能:** 储能技术与政策

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Future of energy storage: technologies and policy

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未来储能:

储能技术与政策

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1. Executive summary

Low carbon sources of energy have significantly reduced storage characteristics in comparison to petroleum, gas and coal. There is therefore a pressing need to develop energy storage technologies (EST) and policy guidance in order to effectively integrate renewable energy sources into the grid, and to create reliable and resilient energy distribution systems. This report of a series of workshops jointly held by the Royal Academy of Engineering and the Chinese Academy of Sciences (CAS) highlights opportunities for the UK and China to work together to accelerate the development of important energy storage technologies and related policy, especially in the area of electrical energy storage relating to transportation and grid applications.

Participants in the academies' workshops identified the following actions as being essential to enable progress in the field of energy storage technologies in both countries:

- Develop more robust systems analysis and modeling.
- Accelerate the deployment of energy storage technology as a matter of urgency.
- Identify funding pathways for EST systems and related infrastructure, including examples of business and governance models.
- Actively encourage collaborative research in selected areas of frontier engineering science.
- Stimulate and recognise energy storage technology innovation through prizes, awards and scholarships.
- Establish a UK-China steering group to develop further collaborative activity.

1. 执行摘要

与石油、天然气和煤炭相比，低碳能源的可存储特性显著降低，因此迫切需要发展储能技术 (EST) 并制定相关引导政策，以使可再生能源有效并网，建立可靠的、适应性强的能源输配网络。根据英国皇家工程院和中国科学院联合召开的一系列研讨会形成的这份报告，强调了中英双方将共同努力加速重要储能技术及相关政策，特别是在与交通及电网应用相关的电力储能领域的发展。

研讨会成员提出了如下措施，这些措施对于推动中英两国储能技术的进步非常重要：

- 发展更强大的系统分析和建模能力。
- 将加快部署储能技术作为紧迫任务。
- 确定储能系统和相关基础设施的资助途径，包括商业和管理模式范例。
- 积极鼓励在选定的前沿工程科学领域开展合作研究。
- 通过奖金、奖励、奖学金等形式激励和认可储能技术创新。
- 建立中英指导组制定下一步合作行动。

2. Policy context

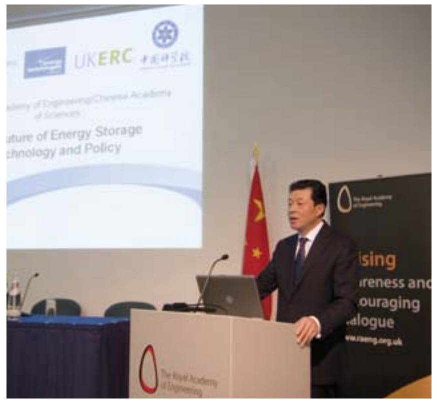
Two high-level workshops were jointly hosted by the Royal Academy of Engineering and the Chinese Academy of Sciences in 2011 to highlight areas where the UK and China might work together to accelerate the development of energy storage technologies (EST) and tackle key technical, manufacturing, commercialisation and policy barriers to the deployment of EST.

The workshops reviewed some of the current drivers for national and regional policy on the development and deployment of energy storage technologies in both countries, with a particular focus on areas of electrical energy storage relating to transportation and grid applications. Over one hundred UK and Chinese experts from academia and industry participated in these workshops, as well as several senior UK and Chinese government stakeholders. Contributions and presentations are available online at: **http://tinyurl.com/bwt5r6r**

This report is intended to capture the key messages delivered by participants at these workshops, and at a follow-up discussion with senior UK and Chinese stakeholders in London in February 2012. The views expressed here are those of participants and not of either national academy. Following the workshops, further initiatives in EST policy development were taken forward, some of which directly addressed the policy recommendations made by workshop participants: a selection of these are listed in section 5 of this report.

The first UK/China Energy Storage Workshop, held in London in January 2011.

第一次中英储能研讨会，2011年 1月，伦敦。



His Excellency Liu Xiaoming, Ambassador of the People's Republic of China, addresses the first UK/China Energy Storage workshop in London.

中国驻英大使刘晓明在第一次中英储能研讨会上讲话。

2. 政策背景

英国皇家工程院与中国科学院于2011年共同举办了两次高层研讨会，重点探讨了中英双方拟加强合作的领域、以加快储能技术的发展，并解决所面临的关键技术、制造、商业化和政策障碍。

研讨会总结了当前两国发展和部署储能技术的国家和区域政策驱动因素，特别关注与交通和电网应用相关的电力储能技术领域。来自中国和英国的100多位专家参加了这两届研讨会，相关资料可从下面网址获取：**http://tinyurl.com/bwt5r6r**。

本报告旨在总结这两次研讨会以及2012年2月在伦敦举行的中英两国主要利益相关方讨论会上所传递的关键信息。报告陈述的观点是研讨会成员的观点，而非皇家工程院和中国科学院的观点。研讨会后，在储能技术政策方面产生了更进一步的活动和报告，其中一些直接形成了研讨会成员的政策建议(参见本报告第5部分)。

Professor Jinghai Li FREng addresses the 2nd UK/SINO Energy Storage Workshop in Beijing in May 2011.

李静海研究员，中英储能研讨会联合主席

Policy challenges and opportunities

Although different energy portfolios, societal drivers and policy frameworks existed in the UK and China, workshop participants felt that both countries shared a common aim of increasing the usage of low carbon energy sources and addressing the challenges of growing and fluctuating demand. Similarly, on the supply side, both countries faced the challenge of changing their mix of energy sources in an economic environment where the lack of a benchmark or transparent price point for electricity or carbon gave rise to considerable uncertainty and risk. The development and deployment of energy storage was seen as a serious option for managing the intermittency of low carbon generation technologies. It could also bring enhanced benefits to electricity networks, including alleviation of transmission and distribution constraints, voltage control optimisation, provision of fast reserve, and, potentially, tools to improve dynamic stability. However, key questions remained, including:

- How much storage was needed?
- What technologies should be developed?
- Where should these technologies be deployed (e.g. grid, city, homes)?

A lack of reliable answers to these questions was felt to be hampering the development of effective low carbon infrastructure, systems and processes. It was also seen as slowing the creation of potential new business opportunities in engineering, manufacturing and the service sector.

政策挑战与机遇

虽然中国和英国有着不同的能源结构、社会驱动因素和政策框架，但都有提高低碳能源使用、解决需求增长和波动挑战的共同愿望。同样地，在供给方面，两国都面临着在电力或碳排放基准或能源定价依据缺失的经济环境中，改变能源结构所导致的不确定性和风险上升的挑战。储能的开发和部署被视为管理间歇性低碳发电技术的一种重要选择。储能的部署还将为电网带来更多益处，包括缓解输配电制约、优化电压控制、提供快速储备以及作为提高动态稳定性的潜在工具。然而，需要考虑的关键问题是：

- 需要多大规模的储能能力？
- 需要开发哪些技术？
- 这些技术应该部署到哪里（如电网、城市、家庭规模)？

缺乏这些问题的可靠答案除了阻碍高效低碳基础设施、系统和工艺的发展，也减慢在工程、制造和服务业等部门创造新商机的可能性。

Energy policies in the UK and China

UK and Chinese government energy policies were principally driven, respectively, by the UK Climate Change Act 2008 **www.legislation.gov.uk/ukpga/2008/27/contents** and the 12th Five Year Plan. Both nations were addressing changes to the mix of energy systems and the need to control consumer demand. Speakers from the UK emphasised the importance of security and pricing of energy provision within a mixture of gas, coal, nuclear and renewable sources. In China, with its much lower use of petroleum, the dominant energy source continued to be coal, though this was being supplemented by major new nuclear build, as well as oil shale, solar, hydroelectric and wind.

Some of the key energy development needs in China arose from the growing demand for vehicles, and the state was engaging with the private sector in examining the role to be played in the transport system by electric technology and batteries. There were likely to be future challenges in meeting growing power demands, especially during the summer peaks in larger cities. There was an acknowledged need for more research and development activity in renewable and sustainable generation, energy storage and smart infrastructure. Government sources believed that in the future a diversified market would evolve, with state and private companies working jointly to develop grid systems and energy storage technologies; workshop participants presented case studies of such evolving relationships.

In China the main drivers for energy storage were strategies to cope with rising industrial and domestic use, especially within fast-growing cities. Here the imperatives to meet societal needs could result in requirements being associated only with particular cities and regions. There were already a number of locations where the electricity supply was not available for industrial customers on a continuous basis; for example, in Guangdong Province, where rationing occurred in an unorganized or reactive manner.

In their presentations, UK speakers focused on the key challenge of making the UK energy system more sustainable (the Climate Change Act target was to lower CO_2 emissions to 80% of their 1990 levels by 2050), without impacting on security or affordability. In the case of transport, the mainstreaming of electric vehicles with improved storage characteristics in tandem with the decarbonisation of energy generation was seen as vital for meeting this target. Speakers attested to the need for nuclear energy provision, a growing commitment to wind power and an acknowledgement of the continuing maturation of other renewable technologies (notably biofuels). The development and deployment at an industrial scale of energy storage technologies was seen as key to managing the intermittency of these and other low carbon generation technologies and to maintaining the security, flexibility and efficiency of the electricity grid.

中国和英国的能源政策

英国和中国政府的能源政策分别主要由《英国气候变化法案2008》（**www.legislation.gov.uk/ukpga/2008/27/contents**）和中国“十二五”规划所衍生。两国都在致力于解决能源体系结构转变和降低消费需求的挑战。英方参会人员强调了天然气、煤炭、核能和可再生能源这一能源结构安全和定价的重要性。而在中国，石油利用比例较低，煤炭占主导地位，不过核电、油页岩、太阳能、水电和风能所占份额正在增加。

在中国，能源发展的部分关键需求来自于日益增长的车辆需求，国家正在与私营部门一同考察电动和电池技术在交通部门能够发挥的更大作用。在满足日益增长的电力需求方面，中国或许将会面临更大的挑战，尤其是在大城市夏季用电高峰期。人们普遍认为需要在可再生和可持续发电、储能和智能基础设施等领域加强研发。政府方面相信，未来将形成一个多元化的市场，国有和私营企业合作开发电网和储能技术。参加研讨会的人员提供了一些这类合作关系的案例。

中国发展储能的主要驱动力是应对不断增长的工业和家庭用电的战略需求，尤其是在快速扩张的城市。目前，满足社会需求的要求可能会导致只能满足特定的城市和地区。一些地方已经出现了无法对工业用户提供连续电力供应的情况，如多个省市或有计划或被动地采取了限电措施。

英方参会人员在发言中主要关注于如何促进英国的能源体系更加可持续发展（《气候变化法案》的目标是，到2050年其二氧化碳排放量相比1990年的水平降低80%），同时不影响其安全性和可负担性方面所面临的一些关键挑战。以交通运输领域为例，人们认为具有改良的储能性能，同时采用脱碳发电的电动汽车成为主流对于实现这一目标至关重要。研讨会发言人员认为需要发展核能，加大风能发展力度，同时关注不断成熟的其他可再生能源技术（特别是生物燃料）。发展和部署工业规模储能技术被视为是应对这些低碳发电技术的间歇性，以及维护电网安全性、灵活性和效率的关键。

Policy landscape for EST in the UK and China

While both countries were developing ESTs of different types and recognized the need for storage, the sector had not to date been granted a high policy profile and was not explicitly embedded in detailed policy documents or plans. When national research and policy priorities around electrical energy systems involving the grid or the transport sector were compared, it was felt that the following key points of difference emerged:

China

- *The limited availability of oil was driving the continued utilisation of coal as the primary electrical power source.*
- *The development of national and global markets based on electric vehicles and associated battery/power consumables was a strong priority. Significant national level financial provision had been made for electric vehicle development (research, demonstration and enterprise) linked with 25 substantial city demonstrator sites (linked as part of a wider eco-agenda).*
- *There had been a focus on electric vehicles for public transport and transport for services. There could be a need to review the focus on electric vehicles compared to other approaches in the future.*
- *There was no direct policy relating to storage at a national level but significant activities underway focused on battery technologies and hybrid systems related to incorporation of renewables (wind, solar) with limited private sector involvement.*

UK

- *There were a number of electric vehicle initiatives with an emphasis on vehicles for private use.*
- *Legislation around de-carbonising industry and society was a strong driver for change and exploration of taxing/charging and business models.*
- *A special 'Office of Low Energy Vehicles' had been established by the UK government to drive policy and change.*
- *The role of regional adoption was important. Examples included 'Transport for London' (hydrogen buses), 'Plugged in Places' (12 towns) and related grid initiatives (e.g. 'Low Carbon London'). The scope of regional projects was, in general, quite modest.*
- *There was no policy relating specifically to storage.*
- *The uncertainties of pricing and marketplace posed challenges for an investor looking for a stable revenue stream.*

中国和英国储能技术的政策环境

虽然中英两国都在发展各种储能技术，并已认识到对储能的需求，但该领域尚未在政策层面上得到高度重视，也没有明确纳入到具体的政策文件或规划。对两国涉及电网或交通部门关于电能系统的研究和政策优先事项进行比较，可以发现以下几个关键差异：

中国：

- 石油的缺乏导致煤炭仍将作为主要电力来源。
- 开发基于电动汽车及相关电池/电源消耗品的全国和全球市场是一个重要的优先事项。国家为电动汽车发展（研究、示范和企业）给予了相当大力度的财政支持，并确定了25个国家电动汽车试验示范区（作为一个更广泛的生态议程的一部分）。
- 中国发展电动汽车是把公共交通作重点，而非英国以小轿车为重点。未来将随着国情变化实时调整。
- 在国家层面目前尚无与储能相关的直接政策，但很多行动正在进行，主要是电池技术以及与大规模吸纳可再生能源（风能、太阳能）的混合储能系统，少数私营部门也在一定程度上参与其中。

英国：

- 已有一些电动汽车计划，重点在家用车辆。
- 有关产业和社会除碳化的立法是税收/收费和商业模式变革与探索的有力驱动。
- 英国政府已成立了“低能耗汽车办公室”，以推动相关政策和变革。
- 地方的作用很重要，例如“伦敦交通”（氢能巴士），“充电场所”（12个城镇）及相关电网计划（例如“低碳伦敦”）等。地区性项目的范围通常都不大。
- 没有与储能明确相关的政策。
- 定价和市场的不确定性为寻找稳定收益流的投资者带来了挑战。

Participants drew attention to several policy and economic impediments to the development and deployment of EST (issues are common to both countries, except where otherwise indicated).

- The opaque pricing for electricity gave rise to business uncertainty which brought additional risk and complexity to the business model.
- Determining the accurate pricing of storage was problematic. Some technologies served a principal purpose of storing energy from renewables but were also considered as energy storage assets of strategic national importance.
- Business models were complex, and differed depending on the site within the grid or industrial process where storage was deployed.
- The ownership of storage technology and storage assets was also complex.
- There was a lack of robust modeling of energy storage systems and economics at all scales of applications. Any such model needed to take economic and human factors into account.
- Resilience of storage in a technical sense and the impact on national security in the UK and China were important elements in the overall modeling and system design.
- In the UK, modest shifts in planned targets for CO_2 emissions would significantly change the optimal energy supply mix (coal, gas, oil, nuclear, renewable) for the country or major region. This meant that there was a high risk that non-optimal solutions may be achieved, with significant fiscal and societal consequences.
- Currently there was a need for stronger alignment between research, development and applications of EST, involving academia, government and the private sector. Market development and strategic direction to address key barriers were both needed.
- Better pathways were needed to develop an analysis that could incorporate different policy assumptions or scenarios and EST deployment strategies.
- In the European context a market of competing energy storage technologies was emerging, e.g. batteries and flywheels, driven by externally created incentives or conditions that did not take the full cost of operation into account.

参会人员提请注意储能技术发展和部署面临的许多政策和经济障碍（除特别说明外两国均相同)。

- 电力定价标准增加了储能技术在商业上的不确定性，给商业模式带来额外的风险和复杂性。
- 难以对储能进行准确定价。一些技术主要用于储存可再生电力，但同时也作为国家战略储能设施。
- 商业模式较为复杂，而且会因电网或工业过程中储能部署的地点不同而不同。
- 储能技术和储能资产的所有权较为复杂。
- 缺少各种应用规模下储能系统及其经济性的强大建模能力。任何这类模型都需要考虑到经济因素和人为因素。
- 储能在技术意义上的灵活性及对中英两国国家安全方面的影响是整体建模和系统设计中的重要因素。
- 在英国，二氧化碳排放规划目标的轻微变化就会显著改变全国或主要地区的最优能源供应结构（煤炭、天然气、石油、核能、可再生能源)。这意味着导致出现非优化解决方案的高风险，并产生重大财政和社会影响。
- 目前，需要在储能技术的研究、开发和应用之间形成包括学术界、政府和私营部门在内的更强大的联盟，并需要通过市场开发和战略指导来解决主要障碍。
- 需要利用更好的方法进行分析，将不同的政策假设或情景及储能技术的部署策略结合起来。
- 在欧洲范围内，一个竞争性技术市场正在出现（如电池、飞轮等)，这个市场受到外部激励措施或环境的驱动，但往往未考虑运行全成本。

Participants felt that the current policy frameworks in both the UK and China actively deterred energy storage solutions. Answers to the above policy, structural and commercial/economic questions could help clarify stakeholders' understanding of the economic and environmental benefits played by storage, which in turn would enable firm revenue streams to be defined for potential investors.

参会人员认为，中英两国目前的政策框架阻碍了储能解决方案的发展。对上述政策、结构和商业/经济问题的解答将有助于阐明利益相关方对储能的经济与环境效益的认识，并有助于为潜在的投资者明确稳固的收益流。

Highview Cryogenic energy storage Demonstrator Plant in Slough, UK

位于英国Slough的Highview低温液态空气储能示范工厂

BYD and the State Grid Corporation of China launch the largest grid battery storage facility in the world. Located in Zhangbei, Hebei Province, China, the 36 Megawatt-hour LiFePO4 battery array covers an area larger than a football field [1] . Four companies which supply battery arrays for this project are: BYD 36MWh; ATL 16MWh; CALB 9MWh; WX 2MWh.

国家电网公司建设的世界最大的电网电池储能设施。该电站位于河北省张北县，拥有36 MWh磷酸铁锂 LiFePO4 电池阵列，占地面积超过一个足球场。共四家公司提供电池，其中BYD 36MWh, ATL 16MWh, 中航锂电 9MWh, 万向2MWh

[1] http://tinyurl.com/cwsnbeh

3. Technology opportunities

Broadly speaking, workshop discussion of opportunities for UK–China collaboration on EST for grid applications focused on the area of demonstration projects, while there was felt to be broader scope for collaboration in EST for transport in research and development activities.

EST for vehicles collaboration opportunities

Both the UK and China were carrying out R&D into energy storage technologies for vehicles. Broadly speaking, innovation in China was driven by a need to make personal transport affordable for citizens who could not otherwise afford it, whereas in the UK it was driven by a need to match the performance of existing well-established technologies. In China there already existed a large and growing market for small scale vehicles, ranging from electric bicycles through very light vehicles up to the classic international small car. In the UK the main driver was academic research and the need to develop cost-effective alternatives to fossil fuels that would support greenhouse gas emissions targets. In both countries the uptake of the small car segment was supported by up-front government capital subsidies.

In China, companies were supported by applied R&D Institutes, which developed product engineering and manufacturing systems. Many of these Institutes were represented at the workshops (full list of attendees available in Appendix 2). The Institutes worked with the many companies which were supplying batteries to the Chinese market for vehicles in all three market segments, and had a significant prototype product development and manufacturing scale-up capability. In the UK, more of the product development was carried out in industry and basic and applied R&D was carried out in universities, though this was often linked to R&D in companies or was itself commercialised through spin-out companies.

The research agendas of both countries were similar, with a greater focus in China on exploiting its access to raw materials (including coal and rare earths) and in the UK a broader range of high quality low-carbon transport research that included hydrogen storage as well as battery technology. The need in China for rapid economic development in areas away from the larger cities meant that the focus was mainly on exploiting a previously existing electricity distribution system, rather than technologies that would require additional distribution systems. Electricity distribution often preceded the delivery of petroleum products, giving light electric vehicles an advantage not seen in the UK.

Closer to market, major product development was taking place in China on battery cost and performance, and motor technology, where the focus was on developing integral motors per wheel and associated traction control and regenerative braking control systems. In the UK, a wide range of applied research activities were being funded, including composite magnet technology for mechanical storage in flywheels, battery and vehicle management systems and lower cost systems for compressed hydrogen storage.

3. 技术机遇

概括而言，研讨会在探讨中英两国电网应用领域储能技术的合作机遇时，其重点集中在示范项目领域，同时与会者认为双方在交通运输领域储能技术的研发方面存在更广阔的合作空间。

车辆相关储能技术的合作机遇

中英两国均在开展车辆储能技术研发。一般而言，中国的储能技术创新来自于让买不起汽车的人们能够拥有个人交通工具的需要，而英国则在于研发与现有的成熟技术性能相匹配的储能技术。中国的小型车辆（包括电动自行车、超轻型车以及经典的国际小型车）市场规模已经很大，并且还在不断增长。而在英国，主要的驱动力是学术研究与开发低成本化石燃料替代品，以支持温室气体排放目标。两国小型汽车的成长在前期都得到了政府的资金补贴。

在中国，企业受到从事产品工程与制造系统开发的应用型研发机构的支持。很多这些研发机构参加了中英研讨会（与会者名单见附录2）。这些研发机构与企业合作，由企业向中国这三类电动车辆市场供应电池，具有强大的原型产品开发与规模化生产能力。在英国，产品的研发更多地由工业界负责，而基础与应用研发集中在高校，尽管后者的研发经常跟企业研发相联系，或者通过成立衍生企业的形式商业化。

中英两国的研究重点是相似的，中国更注重开发原材料的利用途径（包括煤炭与稀土），而英国则是在更大范围内研究高质量低碳交通技术，如储氢和电池技术等。中国偏远地区经济快速发展的需求意味着应着重开发现有的配电系统，而不是那些需要建立额外配电系统的技术。电力分配的普遍性通常高于石油产品的输送，这使得中国轻型电动车拥有较大的优势。

中国的主要产品开发更接近市场，集中在电池成本、性能和电机技术等方面，重点是开发整车及相关牵引控制系统和制动控制系统。在英国，资助的应用研究范围较广，包括飞轮机械储能的复合磁铁技术、电池与车辆管理系统，以及低成本压缩储氢系统等。

Market opportunities

The current market for electric vehicles in China was substantial: around two million electric bicycles were sold each year. There was a growing market of around 100,000 units per year for very light two-seater vehicles that had a top speed of 60km/h and a range of up to 80km; these vehicles used NiMH batteries, with a strong emphasis on cost. There was a small market for vehicles with a range of up to 200km and a performance more typical of a small car; these used Li-ion batteries and cost £20-30,000, after government subsidies were applied; and typical battery weight was 300kg. There was also a luxury or research market for high performing vehicles, as well as various demonstration niche opportunities for city buses, police vehicles etc.

The current market for electric vehicles in the UK was limited but expected to grow within a five year horizon to many thousands of units per year. This would include both all-battery vehicles and plug-in hybrids. Electric vehicles were an important part of the UK long-term strategy for adaptation of the energy system to be resilient to changing energy markets and deliver reductions in greenhouse gas emissions, reducing to levels less than 20% of 1990 energy usage by 2050. UK government policy was focused on vehicles with range and performance, with the goal that a high proportion of UK journeys would be completed using electricity (there was a parallel goal that the carbon dioxide intensity of electricity generation will be reduced by an order of magnitude by early in the decade after 2030). In practice this meant creating a market for electric vehicles through up-front subsidies and so-called 'Plugged-In Places', investments in public recharging infrastructure.

EST for storage collaboration opportunities

The workshops examined energy storage demonstration projects in the UK and China. These were found to be exploring pioneering models for linking research and industry, sometimes in an *ad hoc* fashion.

China had a growing and very significant portfolio of energy storage projects, beyond the Shanghai Expo 2010 demonstrations, which had now developed into a range of regional EST provision options using different types of batteries (as summarised in Appendix 1). The focus was on technical demonstration rather than on economic models. Some high density storage technologies currently at demonstration stage could give rise to workplace and public safety issues, which would require development of appropriate standards and protocols. Most of the key issues were felt to revolve around the three major questions elucidated earlier in this report: How much storage is needed? What technologies should be used? Where on the system should storage be sited? It was felt that trade associations and industry interest groups could be better deployed in this area to link science and technology with commercial factors.

In the UK there were also a number of demonstration projects (listed in Appendix 1), often smaller in scale and covering a range of areas relating to grid and transport activities.

Heat systems were an important focus of research work in both China and the UK. This was not a primary focus of the workshops but its importance should not be under-emphasised – indeed, subsequent to the workshops a number of activities have been stimulated that take forward this aspect (see Section 5).

市场机遇

目前中国电动车的市场规模很大。电动自行车年销量约200万辆。最高时速可达60公里、行驶里程可达80公里的双座超轻型车辆每年的市场增量大约10万辆。这些车辆使用铅酸电池，强调节省成本。最大行驶里程200公里的电动车市场规模较小，这些车使用锂离子电池，政府补贴后的成本约20 000到30 000英镑，电池重量约为300千克。高性能电动车还只是一种奢侈品或仅供研究之用。电动车在城市公交、特种车辆等领域有很多示范机遇。

英国目前的电动车市场规模有限，但未来五年每年有望增加数千辆，这包括所有纯电动车以及插电式混合动力车。电动汽车是英国长期能源战略的重要组成部分，该战略将改造能源体系以适应不断变化的能源市场，减少温室气体排放，到2050年使能源消费量在1990年水平上减少20%。英国政府的政策重点是车辆的行驶里程与性能，目标是使在英国范围内的行程的绝大部分可以仅用电力完成（与此并行的目标是在2030年后的十年内，将发电的二氧化碳排放强度降低一个数量级）。实际上这意味着通过前期补贴和“充电场所”等公共充电基础设施的投资来创造一个电动汽车市场。

存在合作机遇的储能技术项目

研讨会讨论了中英两国的储能示范项目，这些项目旨在探索与研究和产业相连接的先导模式，有时采用的是一种创新的方式。

中国储能项目不断成长，效果显著。2010年上海世博会示范项目，现在已经发展成一系列区域性储能技术选择方案，可以利用各种类型的电池（见附录1），其重点是技术示范而不是经济模式。一些高密度储能技术目前正处于示范阶段，可能会引起工作场所或公众安全问题，这需要制定相应的标准与规则。关键问题大多与本报告前面提到的三个问题有关：需要多大规模的储能？需要使用哪些技术？以及这些技术应该部署到哪儿？贸易协会和行业利益集团在这个领域可以进行更好的部署，使科技更好地跟商业因素挂钩。

英国也有一些示范项目（见附录1），这些项目通常规模较小，涵盖了电网与交通活动的相关领域。

无论中国还是英国，储热系统都是研究工作的重点之一。这虽然不是研讨会的主要重点，但其重要性不应被忽略，事实上，研讨会后在这方面已产生了一些活动（见第5部分）。

Opportunities for UK-China collaboration

Despite structural differences in the ways in which EST research was carried out, the specific development targets across both countries were nevertheless seen as quite similar. This combination of different approaches and similar targets meant that there were a number of potential opportunities for collaboration, some of which are described below.

Opportunities for collaboration on EST on the grid included:

- whole systems analysis of the economic and environmental assessment of storage
- technology maps that accounted for lifetime and whole systems approaches
- bottom-up transformational research to break through the high costs of current solutions
- enhanced lifetime of some energy storage systems
- demonstration projects research
- underpinning frontier engineering science.

In the area of transport, research on battery technologies was seen as most important. Areas where collaboration could take place included:

- integrated energy-transportation systems analysis
- safety and design of high energy density storage devices
- alternative materials with different cost and supply chain characteristics
- progress in fast and deep charging
- battery chemistry and materials recycling
- cell and battery pack manufacturing development
- motors and hybrid technologies.

Demonstration sites and demonstrator cities also provided opportunities for collaboration. Participants pointed to a good deal of uncertainty and risk in the system specification and implementation of demonstrator sites. Potential areas for collaboration to address this uncertainty included:

- whole systems analyses (where the UK has particular strengths)
- frontier science to solve efficiency, lifetime and cost issues in a range of energy storage devices
- business and process modeling for the different infrastructures in China and the UK
- evaluation of options for systems analysis and servicing of integrated energy storage devices
- exploration of governance and ownership models.

中英两国的合作机会

尽管中英两国在储能技术方面的研究存在结构化差异，但具体发展目标非常相似。不同方式与相似目标的结合意味存在着许多潜在的合作机会，其中一些如下所述。

电网领域储能技术的合作机会包括：

- 储能的经济与环境评估全系统分析
- 寿命和全系统方法的技术路线图
- 可突破现行方案高成本问题的自下而上的变革性研究
- 寿命更长的储能系统
- 新技术示范
- 基础前沿科学。

在交通领域，电池技术的研究是最重要的，可以开展合作的领域包括：

- 综合能源-运输系统分析
- 高能量密度储能设备的安全性与设计
- 具有不同成本与供应链特性的替代材料
- 快速深度充电过程
- 电池与电池材料回收
- 电池单元与组件制造技术开发
- 电机与混合动力技术。

示范地点与示范城市也提供了合作机会。与会者指出了在系统规范与示范地点实施方面存在着大量不确定性和风险。解决这些不确定性的潜在合作领域包括：

- 全系统分析（英国具有特别的优势）
- 解决大范围储能设备的效率、寿命和成本问题的前沿科学
- 中国与英国不同基础设施的业务与流程建模
- 系统分析与集成储能设备服务的选择方案评价
- 管理与所有权的探索。

4. Recommendations

Participants in these workshops concluded that the operation of EST and the economic, strategic and environmental value of EST embedded in the supply grid have not been sufficiently well understood. This situation could result in the risk of uneconomic and inappropriate supply and management systems being created. Participants recommended two broad types of activity be undertaken to address these uncertainties.

A thorough, multifactorial systems analysis of the economic and environmental impact of storage needed to be undertaken. In order to attract continued financial and political investment and support, it was essential that a technology and engineering road map be produced in each country, taking a whole systems approach across the lifespan of the technologies, bearing in mind the differing scale of need in each country and the differing levels of maturity of the energy systems, as well as differences in the legal and regulatory frameworks.

Complementary to this high level top-down approach, a bottom-up development of transformational research programmes should be undertaken to break through the high costs of current solutions, if necessary invoking innovative business models for whole life value assessment and revenue collection. This should address the longevity and effectiveness of energy storage systems and include demonstration projects, and production and manufacturing research as well as underpinning frontier science and engineering research.

Key needs for the development of energy storage technologies in both countries were felt to include:

- rigorous systems and services analysis to allow exploration of business models that illustrated options and value for adoption of energy storage devices for personal, regional and industrial scales of use
- regional (city) based demonstration projects of electric vehicles and, for example, battery technologies
- integrated economic and technical modelling of smart networks and how they may evolve
- encouragement of alternative storage materials, technologies and advanced or innovative manufacturing methods that could yield transformational cost reductions
- governance in the regulatory and operational management of energy systems
- public safety and the safe and effective recycling of energy storage materials.

4. 建议

研讨会成员指出，储能技术的运行及其嵌入到供应网络中的经济价值、战略价值和环境价值尚未得到充分了解。这可能导致创建的供应和管理系统出现不经济和不合适的风险。研讨会成员建议采取两方面措施来解决这些不确定性问题。

需要开展储能经济和环境因素影响的全面、多因素系统分析。为吸引持续的财政投入和政策支持，两国非常有必要各自制定一份技术和工程路线图，在各种储能技术的生命周期内采用全面的系统方案，同时考虑两国在需求规模上的差异、能源体系成熟度的不同以及法律和规范框架的差别。

作为这一高层次自上而下方案的补充，需要开展一个自下而上的变革性研究计划，突破目前储能技术方案的高成本问题。如果有必要可采用创新的商业模式进行全生命周期价值评估和税收征管。这将解决储能系统的寿命和有效性问题，还包括示范项目、生产和制造研究以及基础前沿科学和工程研究。

中英两国发展储能技术的关键因素包括：

- 严格的系统和服务分析，以探索适用于个人、地区和工业规模应用的储能设备选择方案及其价值的商业模式
- 针对电动车和电池技术的地区（城市）示范项目
- 完整的智能网络经济和技术建模及其发展
- 鼓励发展新一代储能材料、技术和先进或创新的制造方法，大幅降低成本
- 能源体系的监督和运行管理
- 公共安全以及储能材料的安全高效回收利用。

Specific recommendations were made to governments, city regions, funding bodies and industrial partners:

- Develop more robust systems analysis and modeling that examine the total system operation. It is necessary to accommodate multi-dimensional spatial and temporal scale and levels (techno-societal-economic) in order to understand the options for utilisation of EST and the total market opportunity. This is a prerequisite in the development of policies for future deployment of EST.
- Accelerate the deployment of energy storage technology. This can be achieved through enhancing the visibility of demonstration projects, their design and their outcomes, including overall economic costs and benefits. It is proposed that a geographical directory showing details of EST demonstrations could be collated and promoted (e.g. battery parks, super capacitors, compressed air storage, underground thermal, heat storage, cryogenic/phase change processes, fuel cells, flywheels, pumped hydroelectric etc).
- Identify funding pathways for EST systems and related infrastructure, including examples of business and governance models. It is to be noted that there are likely to be significant economic benefits for new businesses in this sector relating to engineering technology and service sectors.
- Actively encourage collaborative research in selected areas of frontier engineering science noting the current relevance of specialist areas that embrace: new materials for thermal storage; redox flow battery design, manufacturing and operational testing; methods for storage of low grade heat/cold; improved Li-ion and other advanced battery materials; liquid gas cryogenic storage; energy storage management and power electronics; hybrid technologies in vehicles. There should be a focus on research that could provide breakthrough outcomes to reduce cost, enhance reliability or improve safety of EST.
- Recognise and promote innovation in EST through prizes, awards and scholarships. There should be particular thought given to opportunities to encourage and support trans-national teams working in this area. The national academies and institutions could contribute through facilitating lectures, debates and communications, and/or annual workshops to share good practice and results of demonstration projects.
- Establish a senior UK-China steering group to develop further collaborative activity arising from these recommendations. This small group would include business leaders in recognition of the emerging and significant business opportunities for small and large enterprises.

报告为政府、城市管理部门、资助机构和工业伙伴提出的具体建议如下：

- 发展更强大的可监测整个系统运行情况的系统分析和建模能力。应使其能够进行多维空间和时间尺度和多层面（技术-社会-经济）分析，以了解储能技术应用的选择方案和市场机遇。这是制定储能技术未来部署政策的先决条件。
- 加快储能技术的部署。可以通过加强示范项目的可预见性、项目设计和产出来实现，包括整体经济成本和效益等。有建议提出可制作一份显示储能示范项目细节的地理目录（如电池区、超级电容器区、压缩空气储能区、地下蓄热区、储热区、低温/相变工艺区、燃料电池区、飞轮区、抽水蓄能区等）。
- 确定储能系统和相关基础设施的资助途径，包括商业和管理模式范例。需要注意的是，在此领域与工程技术和服务部门相关的新业务很有可能具有显著的经济效益。
- 积极鼓励在选定的前沿工程科学领域开展合作研究，包括：储热新材料，液流电池的设计、制造与运行测试，低品位热能/冷能的储存方法，改进型锂离子电池和其他先进电池材料，液化气体低温储存，储能管理与电力电子技术，汽车混合动力技术、集成技术及热电调峰管理等。关注有可能在降低储能技术成本、增强其可靠性或改善其安全性方面产生突破性成果的研究。
- 通过奖金、奖励和奖学金等形式认可和促进储能技术创新。特别应该鼓励和支持跨国团队在此领域开展研究。国立科研院所可通过推动开展学术讲座、讨论、交流等活动做出贡献，并且可通过召开年度研讨会的方式来共享示范项目的最佳实践和结果。
- 建立中英高层指导小组制定根据上述建议的下一步合作行动。这一小组还将包括认识到储能能为大小企业带来新兴和重大商业机遇的商界领袖。

5. Activities following the workshops

Following the workshop, many energy storage stakeholders in the UK and China have taken forward specific activities and reports that address some of the key recommendations made above. Examples of these activities carried out to date are listed below. Readers interested in more detail on the performance and development of energy storage technologies are referred to the reports below (figure 3.1 of the Centre for Low Carbon Futures report, *Pathways for Energy Storage in the UK*, gives a particularly good overview of the performance of basic EST devices).

- Energy Storage Funders Round Table – to discuss implementation and financing of EST systems in UK (Energy Research Partnership)[2].
- *Pathways for Energy Storage in the UK* – a report highlighting current status and barriers to implementation of EST in the UK (Centre for Low Carbon Futures)[3].
- *Strategic Assessment of the Role and Value of Energy Storage Systems in the UK Low Carbon Energy Future* report (Carbon Trust study led by Professor Goran Strbac of Imperial College London published by the Energy Futures Lab at Imperial College London)[4].
- Grand Challenge Competition Funding on Systems Analysis and Technology Development for Grid Storage – for UK researchers and a new road-mapping fellowship (Engineering and Physical Sciences Research Council)[5].
- *Challenges for Future Energy Storage* report (Energy Research Partnership)[6].
- *Energy Storage Technology* – new journal launched in China (Chinese Academy of Sciences).
- Energy Storage International Conference (June 2012) – focusing on developments and needs in China around materials and leadership (Chinese Academy of Science).
- Foreign and Commonwealth Office China Prosperity SPF Programme – bids made under the low carbon climate change theme relating to energy storage in China[7].
- SUPERGEN meeting and new development programme relating to hydrogen technology[8].
- Low Carbon Innovation and Coordination Group – recent formation and call for development projects (Energy Technologies Institute).
- A joint research centre established by The Centre for Low Carbon Futures, the University of Leeds and the Institute of Process Engineering of the Chinese Academy of Sciences to develop next generation energy storage systems[9].

[2] http://tinyurl.com/ce6uzts
[3] http://tinyurl.com/cxpjfx2
[4] http://tinyurl.com/cnj8cbk
[5] http://tinyurl.com/cksw9jh
[6] www.energyresearchpartnership.org.uk/dl291
[7] http://tinyurl.com/cdu6ydu
[8] www.supergen14.org
[9] http://tinyurl.com/bsgqf8y

5. 研讨会后续行动

研讨会后，中英两国众多储能技术利益相关方已经采取了具体行动或发布了相关报告，以响应前文提出的关键建议。到目前为止开展的活动范例如下所示：：

- 储能资助者圆桌会议——讨论英国储能系统的实施与资助情况（英国能源研究合作论坛）[3]。
- 《英国的储能途径》——这份报告重点描绘了英国储能系统现状和实施障碍（低碳未来中心）[4]。
- 《英国低碳能源未来》报告中的储能系统作用与价值的战略性评估（报告由伦敦帝国理工学院Goran Strbac教授领导的碳信托基金展开研究，由伦敦帝国理工学院能源未来实验室发布）[5]。
- 电网储能系统分析与技术开发"大挑战"竞争性资助，为英国研究人员以及新设立的路线图奖学金提供资助（工程与自然科学研究理事会）[6]。
- 《未来储能挑战》报告（英国能源研究合作论坛）[7]。
- 《储能技术》期刊创刊（中国科学院）。
- 国际储能大会（2012年6月），专注于中国储能相关材料和领导能力的发展与需求（中国科学院）。
- 英国外交和联邦事务部的中国繁荣战略项目基金 China Prosperity SPF Programme，为低碳气候变化主题下的中国储能项目提供支持[8]。
- SUPERGEN会议以及与氢能技术相关的新的开发计划[9]。
- 新近成立了低碳创新与协调组，进行相关开发项目招标（英国能源技术研究所）。
- 英国低碳未来中心、利兹大学以及中国科学院过程工程研究所成立联合研究中心，合作开发下一代储能系统[10]。

Appendix 1: Major Demonstration Projects in China and the UK

Table 1: Examples of energy storage projects and demonstrations currently active in the UK.

Serial 序号	Owner / operator 所有者/运营者	Date of installation 装机日期	Technical details 技术参数	Location 示范地点	Project lead 联系人
1	SSE[10]	2010	Zinc bromine flow battery 150 kWh (manufacturer Premium Power) 锌溴液流电池 150 kWh (制造商: Premium Power) Comparison of ZnBr technology against existing lead acid systems 锌溴技术与现有铅酸系统的比较	Nairn Substation 奈恩变电站	David MacLeman
2	SSE[11]	2011	1 MW, 6 MWh Sodium sulphur battery (supplier S&C Electric, manufacturer NGK) 1 MW, 6 MWh钠硫电池 (供应商: S&C Electric，制造商: NGK) Frequency support and daily peak shaving 频率支持和日常调峰	Lerwick Power Station Shetland Islands 设得兰群岛勒威克电站	David MacLeman
3	SSE	2011	4 MW / 135 MWH thermal storage tank 4 MW / 135 MWh蓄热罐 Storage of excess wind generation 储存剩余风电	Shetland Islands 设得兰群岛	David MacLeman
4	Highview Power Storage[12]	2010	300 kW, 4 MWh cryogenic energy storage (supplier Highview Power Systems) 300 kW, 4 MWh低温储能 (供应商：Highview Power Systems) Demonstration project for peak shaving / reserve duties 调峰/储能示范项目	Slough 斯劳	Toby Peters

附录1 中英两国主要示范项目

表1 英国当前正在运行的储能示范项目.

Serial 序号	Owner / operator 所有者/运营者	Date of installation 装机日期	Technical details 技术参数	Location 示范地点	Project lead 联系人
5	UK Power Networks[13] 英国能源网络[133]	2010	200 kWh Lithium Ion battery (600 kVAr peak) supplier ABB / SAFT 200 kWh 锂离子电池 (600 kVAr峰值) 供应商: ABB/SAFT Demonstration project for distribution voltage support 配电电压支持示范项目	Hemsby, Norfolk 赫姆斯比,诺福克	Peter Lang
6	EFDA / JET[14]		Flywheels 2 * 400 MW peak, 3750 MJ 飞轮储能 2 * 400 MW 峰值，3750 MJ	Culham	Alan Parkin

[10] www.sse.com/PressReleases2008/PremiumPowerCorporationInvestment/

[11] www.sse.com/Lerwick/ProjectInformation/

[12] www.highview-power.com/wordpress/?page_id=1320

[13] www.ukpowernetworks.co.uk/

[14] www.jet.efda.org/focus-on/jets-flywheels/flywheel-generators/

Table 2: Examples of planned electricity storage projects and demonstrations in the UK: excludes large scale pumped hydro and systems intended solely for uninterruptible power supplies. Some projects which are commercially sensitive have been excluded.

表2 英国规划中的电力储能示范项目

(不包括大型抽水蓄能和仅用于不间断供电的项目，部分具有商业敏感性项目亦不在此列)

Serial **序号**	**Owner / operator** **所有者/运营者**	**Technical details** **技术参数**	**Location** **示范地点**	**Project lead** **联系人**
1	CE Electric	Range of technologies for low carbon network fund comparison project with sizes ranging from 2.5 MVA 5 MWh to 50 kVA 100 kWh 低碳网络基金对比项目，规模范围在2.5 MVA 5 MWh到50 kVA 100 kWh之间	North East England 英格兰东北部	Jim Cardwell
2	SSE	Northern Islands storage park, low carbon network fund project 北部岛屿储能园区，低碳网络基金项目	Shetland Islands 设得兰群岛	Stewart Reid
3	ETI[15]	500 kW up to 1500 kW energy storage demonstration 500 kW-1500 kW储能示范项目	Midlands 米德兰	info@eti.co.uk
4	WPD	Energy storage to be included in a smart grid application for low carbon network fund project 低碳网络基金项目，智能电网应用中的储能项目	Bristol 布里斯托尔	Roger Hey
5	SSE	Lithium battery development project application under the low carbon network fund 低碳网络基金项目中的锂电池开发项目	Thames Valley 泰晤士河谷	Stewart Reid

[15] www.eti.co.uk/news/article/eti_invest_14m_in_energy_storage_breakthrough_with_isentropic

Table 3: Examples of currently operational energy storage projects or demonstrations in China

表3 中国已有示范项目

Technology **技术名称**	**Technical details** **技术参数**	**Location** **示范地点**	**Photo** **网站或图片**	**Project lead** **联系人**
Vanadium redox flow battery (VRB) 全钒液流储能电池	2kW/10kWh: lifetime testing system 寿命测试系统	Dalian Liaoning Province 辽宁大连	Fig.1 图1	Dr Xiaoli Wang
	100kW/200kWh: supplied to national grid for grid connection testing 供应于国家电网的电力接入测试系统	Beijing 北京	Fig.2 图2	
	5kW/50kWh: off grid PV-VRB joint power supply system 离网光伏-液流储能电池联合供电系统	Tibet 西藏	Fig.3 图3	
	60kW/300kWh: a building integrated PV with VRB in Dalian Rongke Power Company 融科公司光伏-液流储能电池集成建筑	Dalian Liaoning Province 辽宁大连	Fig.4 图4	
	3.5kW/54kWh: PV-VRB joint power supply systems for telecom stations of China Mobile and China Unicom 中国移动公司和联通公司的通讯基站用光伏-液流储能电池联合供电系统	Dalian Liaoning Province 辽宁大连	Fig.5 图5	
	80kW/160kWh: supplied to national grid for grid connection testing 供应于国家电网的电力连接测试系统	Beijing 北京	Fig.6 图6	
	500kW/1000kWh: grid connection testing 电力连接测试系统	Dalian Liaoning Province 辽宁大连	Fig.7 图7	

Table 3 continued

续表3

Technology **技术名称**	**Technical details** **技术参数**	**Location** **示范地点**	**Photo** **网站或图片**	**Project lead** **联系人**
Large capacity NAS battery energy storage system 大容量钠硫电池储能技术	(1) Shanghai electricity/wind/photovoltaic energy storage system, 100KW/800KWh, completion date: 12-2013 上海电气风光储系统，100KW/800KWh；建成时间2013年12月 (2) Shanghai Jiading green energy building energy storage system, 100KW/800KWh, completion date: 6-2014 上海嘉定绿色节能建筑系统储能，100KW/800KWh；建成时间2014年6月 (3) Shanghai Chongming Island wind/photovoltaic energy storage system, 2MW/16MWh, completion date: 10-2014 上海崇明岛风光储系统，2MW/16MWh；建成时间2014年10月 (4) Shanghai Hongqiao central business district substation storage system, 2MW/16MWh, completion date: 6-2014 上海虹桥商务区变电站储能系统，2MW/16MWh；建成时间2014年6月	Shanghai 上海	Fig8 图8	Prof Zhaoyin Wen 温兆银教授

Table 3 continued

续表3

Technology **技术名称**	**Technical details** **技术参数**	**Location** **示范地点**	**Photo** **网站或图片**	**Project lead** **联系人**
Advanced large scale compressed air energy storage system 先进大规模压缩空气储能系统	Power: 1.5 MW Pressure: 70-200bar Energy density: 50-200 kWh/m3 Efficiency: 50-65% 功率: 1.5 MW 压力: 70-200bar 储能密度: 50-200 kWh/m3 效率: 50-65%	Langfang, Hebei Province 河北廊坊		Prof Haisheng Chen 陈海生教授
Superconducting magnetic energy storage system (SMES) 超导储能系统	The 1MJ/0.5MVA superconducting magnetic energy storage system (SMES) is the first high temperature SMES energized in the power system. 1MJ/0.5MVA超导储能系统是目前世界上并网运行的第一套高温超导储能系统	Baiyin, Gansu province 甘肃省白银市	Fig 9 图9	Dr Wenyong Guo 郭文勇博士

Table 4: Examples of planned energy storage projects or demonstrations in China

计划示范项目

Technology **技术名称**	**Technical details** 技术参数	**Location** 示范地点	**Completion date** 完成日期	**Project lead** 联系人
Vanadium redox flow battery (VRB) 全钒液流储能电池	10kW/100kWh, an off-grid PV-VRB system power 10kW/100kWh, 为独立蛇岛供电的离网光伏-液流储能电池系统	Dalian, Liaoning Province 辽宁大连	2011.8	Dr Xiaoli Wang 王晓丽博士
	60kW/600kWh, a VRB system installed in electrical vehicle station for load leveling 60kW/600kWh, 平衡负载型电动车充电站用液流储能电池系统	Dalian, Liaoning Province 辽宁大连	2011.8	
	200kW/800kWh, supplied to Gold Wind Science &Technology company for smart grid study 60kW/600kWh, 供应于金凤科技公司智能电网研究系统	Beijing 北京	2011.10	
	5MW/10MWh, will be installed in a 50MW wind farm for output smoothness 将安装于50MW风场中用于平滑风电输出。	Fuxin, Liaoning Province 辽宁阜新	2012	

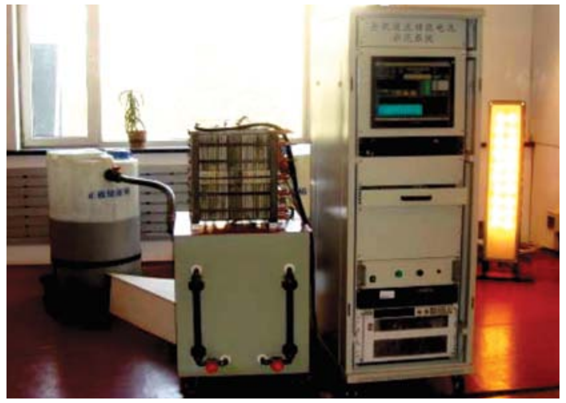


Fig.1 A 2kW/10kWh VRB system for lifetime evaluation

图1 用于寿命评价的2kW/10kWh液流电池系统

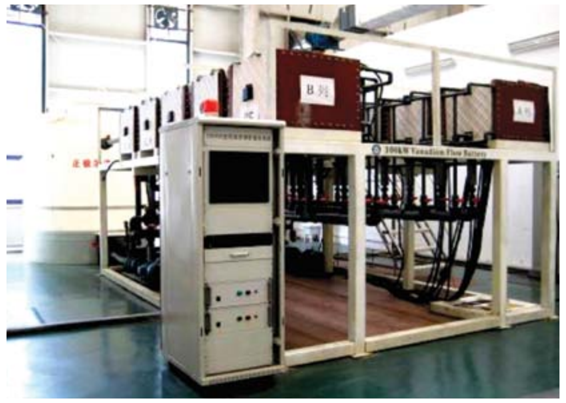


Fig.2 A 100kW/200kWh VRB system for grid connection system

图2 用于电网平稳性测试的100kW/200kWh液流电池系统

Fig.3 A 5kW/50kWh VRB system for off-grid PV-VRB joint power supply system in Tibet

图3 西藏5kW/50kWh离网光伏-液流电池联合供电系统液流

Fig.4 A 60kW/300kWh VRB system in Rongke Power Company R&D building

图4 融科公司研发大楼60kW/300kWh液流电池系统

Fig.5 A 3.5kW/54kWh VRB system for telecom station

图5 通信基站用3.5kW/54kWh液流电池系统

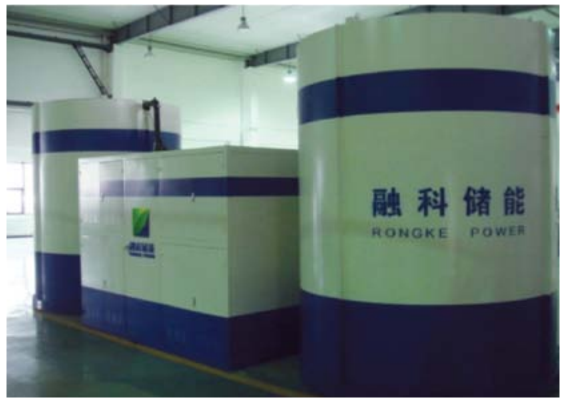


Fig.6 A 80kW/160kWh VRB system for grid connection testing in National Grid of China

图6 国家电网用于电网连接测试的80kW/160kWh液流电池系统

Fig.7 A 520kW/1000kWh VRB testing system

图7 520kW/1000kWh液流电池测试系统

Fig.8 A 100KW/800KWh energy storage system

图8 100KW/800KWh 钠硫电池储能系统

Fig.9 1MJ/0.5MVA , the whole system of SMES

图9 1MJ/0.5MVA, 超导储能系统整体外观

Appendix 2: Participants in workshops and review group

附录2 研讨会成员和评议组成员

Name **姓名**	**Company/institution** **所属机构**
Dr Shafiq Ahmed	The Royal Academy of Engineering 英国皇家工程院
Mr Jeremy Barnett	St Pauls Chambers
Dr Fabrice Bidault	Imperial College 伦敦帝国理工学院
Prof Nigel Brandon OBE FREng	Imperial College 伦敦帝国理工学院
Prof Peter Bruce	University of St Andrews 圣安德鲁斯大学
Prof Haisheng Chen 海生 陈	Institute of Engineering Thermophysics, Chinese Academy of Sciences 中国科学院工程热物理研究所
Prof Liquan Chen 立泉 陈	Institute of Physics, Chinese Academy of Sciences, China 中国科学院物理研究所
Prof Brian Collins CB FREng	Department of Business, Innovation and Skills and Department for Transport (Now at University College London) 英国商业、创新与技能部、英国交通部
Mr Timothy Cooper	UKERC - The Meeting Place 英国能源研究中心-The Meeting Place
Ms Gemma Cope	University of Nottingham 诺丁汉大学
Mr Cuong Dang	The Royal Academy of Engineering 英国皇家工程院
Mr Keith Davis	The Royal Academy of Engineering 英国皇家工程院
Mr Fabian Davola	GSF Capital
Mr Jason Dean	National Nuclear Laboratory 英国国家核实验室
Prof Yulong Ding 玉龙 丁	Leeds University 利兹大学

Name 姓名	Company/institution 所属机构
Prof Jianping Fan 建平 樊	Shenzhen Institute of Advanced Technology, Chinese Academy of Sciences 中国科学院深圳先进技术研究院
Mrs Helen Farr	The IET
Prof Yongling Fu 永领 付	Beihang University 北京航空航天大学
Dr Ajay Gambhir	Imperial College 英国伦敦帝国理工学院
Dr Graeme Gardiner	University of Bath 英国巴斯大学
Dr Tim Green	Imperial College 英国伦敦帝国理工学院
Mr Philip Greenish CBE	The Royal Academy of Engineering 英国皇家工程院
Prof Clare Grey	Cambridge University 英国剑桥大学
Mr Philipp Grünewald	Imperial College London 英国伦敦帝国理工学院
Mr Wenyong Guo 文勇 郭	Institute of Electrical Engineering, CAS 中国科学院电工研究所
Mr Guodong Fan 国栋 樊	Dongda Energy Storage Materials 河南东大高温节能材料有限公司
Dr. Jingdong He 京东 何	Chinese Academy of Sciences 中国科学院
Prof Peter Hall	University of Strathclyde 斯特拉斯克莱德大学
Dr Laurence Hardwick	University of St Andrews 圣安德鲁斯大学
Dr Simon Harrison	Mott MacDonald
Mr Andrew Haslett FREng	ETI 英国能源技术研究所
Dr David Hodgson	UK Trade & Investment 英国贸易投资总署
Mr Graham Howes	BP Alternative Energy BP公司替代能源部

Name 姓名	Company/institution 所属机构
Mr Yong Liu 勇 刘	Escn 中国储能网
Ms Chun Ann Huang	University of Oxford 牛津大学
Prof Weiguang Huang 伟光 黄	Shanghai Advanced Research Institute, Chinese Academy of Sciences 中国科学院上海高等研究院
Prof Xuejie Huang 学杰 黄	Institute of Physics, Chinese Academy of Sciences 中国科学院物理研究所
Dr Huibin Zhao 慧斌 赵	Chinese Academy of Sciences 中国科学院
Prof Saiful Islam 英国巴斯大学	University of Bath
Prof Philip John FREng	Cranfield University 英国克兰菲尔德大学
Dr Martin Johnston	The Carbon Trust 英国碳信托基金
Prof Ke Liu 科 刘	National Institute of Clean & Low-Carbon Energy 北京低碳清洁能源研究所（神华集团）
Prof Roger Kemp FREng	Lancaster University 兰开斯特大学
Ms Emma Kendrick	Sharp Plc 夏普Plc
Ms Helen Knight	New Scientist 《新科学家》杂志
Mr Tim Kruger	University of Oxford 牛津大学
Dr Anthony Kucernak	Imperial College 英国伦敦帝国理工学院
Mr Ashwin Kumaraswamy	EV Group EV集团
Prof Xiaokang Lai 小康 来	Director, China Electric Power Research Institute, China 中国电力科学研究院
Mr Phil Lawton	National Grid 英国国家电网

Name 姓名	Company/institution 所属机构
Prof Jinghai Li FREng 静海 李	Chinese Academy of Sciences 中国科学院
Mr Bo Li 波 李	Azure International 安元易如
Prof Xiaochun Li 小春 李	Institute of Rock and Soil Mechanics, Chinese Academy of Sciences 中国科学院武汉岩土力学研究所
Mr Sheng Li 晟 李	China Datang Corporation (CDT) 中国大唐集团
Mr Xiuzhen Lin 秀贞 林	Baosteel 宝山钢铁公司
Ambassador Xiaoming Liu 晓明 刘	Chinese Embassy 中国驻英大使馆
Prof Qingfen Liu 庆芬 刘	Institute of Process Engineering, Chinese Academy of Sciences 中国科学院过程工程研究所
Mr John Loughhead OBE FREng	UK Energy Research Centre 英国能源研究中心
Dr Ron Loveland	Energy Advisor, Wales government, UK 威尔士议会政府工业及可持续能源部主任
Prof David MacKay OBE FRS	Chief Scientific Advisor to Department of Energy and Climate Change 英国能源和气候变化部首席科学顾问
Mr David Marks	Transmatic Fyllan Ltd
Dr Juan Matthews	UK Trade and Investment 英国贸易投资总署
Mr Shane McHugh	The Royal Academy of Engineering 英国皇家工程院
Dr Nafees Meah	Department for Energy and Climate Change 英国能源和气候变化部
Mr John Miles	Arup
Mr Rob Morgan	Highview Power Storage
Ms Solmaz Moshiri	Highview Power Storage
Mr Duncan Neish	Institution of Civil Engineers 英国土木工程师学会
Dr Gregory Offer	Imperial College London 英国伦敦帝国理工学院

Name 姓名	Company/institution 所属机构
Dr Andrew Oldfield	Second Mile Ltd
Ms Emma Owen	Department of Energy and Climate Change 英国能源和气候变化部
Prof John Perkins CBE FREng	Department for Business, Innovation and Skills 英国商业、创新与技能部
Mr Toby Peters	Highview Power Storage
Prof Mohammed Pourkashanian	Leeds University 英国利兹大学
Mr Alan Powderham FREng	Mott MacDonald 莫特麦克唐纳
Dr Jon Price	Centre for Low Carbon Futures 低碳未来中心
Mr Anthony Price	Swanbarton Ltd
Dr Jonathan Radcliffe	Energy Research Partnership 英国能源研究合作论坛
Dr Radu Șerban	Embassy of Romania 罗马尼亚大使馆
Dr Akeel Shah	Southampton University 南安普敦大学
Dr Hayaatun Sillem	The Royal Academy of Engineering 英国皇家工程院
Prof Bob Slade	University of Surrey 萨里大学
Mr Jonathan Slater	Energy Storage Challenge
Dr Robert Sorrell	BP
Dr Vladimir Stanojevic	Imperial College 英国伦敦帝国理工学院
Ms Cosima Steiner	Austrian Embassy 奥地利大使馆
Dr Goran Strbac	Imperial College 英国伦敦帝国理工学院
Ms Gabi Tait	UKERC - The Meeting Place 英国能源研究中心- The Meeting Place

Name 姓名	Company/institution 所属机构
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Prof Peter Taylor	Leeds University 英国利兹大学
Mr Shulong Teng 树龙 滕	Beijing Energy Investment Holding Co., Ltd. 北京能源投资（集团）股份有限公司
Mr Wei Tong 威 童	Chinese Embassy 中国驻英大使馆
Dr Alan Walker	The Royal Academy of Engineering 英国皇家工程院
Prof Stein Wallace	Lancaster University 兰开斯特大学
Dr Fang Wang	University of Sussex 苏塞克斯大学
Dr Meihong Wang	Cranfield University 克兰菲尔德大学
Ms Dongyao Wang 东瑶 王	Chinese Academy of Sciences 中国科学院
Prof Deyu Wang 德宇 王	Ningbo Industrial Technology Research Institute, Chinese Academy of Sciences 中国科学院宁波工业技术研究院
Prof Lifang Wang 丽芳 王	Institute of Electrical Engineering, Chinese Academy of Sciences 中国科学院电工研究所
Dr Francis Wang	National Institute of Clean and low carbon Energy (NICE)
Mr Zhongcheng Wang 仲成 王	Chinese Embassy 中国驻英大使馆
Prof Fei Wei 飞 魏	Tsinghua University, China 清华大学
Prof Weiguang Huang 伟光 黄	Shanghai Advanced Research Institute, Chinese Academy of Sciences 中国科学院上海高等研究院
Prof Zhaoyin Wen 兆银 温	Shanghai Institute of Ceramics, Chinese Academy of Sciences 中国科学院上海硅酸盐研究所
Prof Xuhui Wen 旭辉 温	Institute of Electrical Engineering, Chinese Academy of Sciences 中国科学院电工研究所

Name 姓名	Company/institution 所属机构
Prof Tony West	University of Sheffield 谢菲尔德大学
Prof Richard Williams OBE FREng	University of Leeds 利兹大学
Mr Grant Wilson	University of Sheffield 谢菲尔德大学
Mr Nick Winser	National Grid 英国国家电网
Prof Baojia Xia 保佳 夏	Shanghai Institute of Microsystem And Information Technology 中国科学院上海微系统与信息技术所
Mr Liye Xiao 立业 肖	Institute of Electrical Engineering,CAS 中国科学院电工研究所
Mr Jun Yin	Bloomberg New Energy Finance 彭博新能源财经
Dr Vladimir Yufit	Imperial College 英国伦敦帝国理工学院
Prof Huamin Zhang 华民 张	Dalian Institute of Chemical Physics, Chinese Academy of Sciences 中国科学院大连化学物理研究所
Prof Suojiang Zhang 锁江 张	Institute of Process Engineering, Chinese Academy of Sciences 中国科学院过程工程研究所
Prof Dadi Zhou 大地 周	Energy Research Institute, National Development and Reform Commission 国家发改委能源研究所

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We provide analysis and policy support to promote the UK's role as a great place from which to do business. We take a lead on engineering education and we invest in the UK's world class research base to underpin innovation. We work to improve public awareness and understanding of engineering.

We are a national academy with a global outlook and use our international partnerships to ensure that the UK benefits from international networks, expertise and investment.

The Academy's work programmes are driven by four strategic challenges, each of which provides a key contribution to a strong and vibrant engineering sector and to the health and wealth of society:

Drive faster and more balanced economic growth

Foster better education and skills

Lead the profession

Promote engineering at the heart of society

面向国家战略需求,面向世界科学前沿,加强原始科学创新,加强关键技术创新与集成,攀登世界科技高峰,为我国经济建设、国家安全和社会可持续发展不断做出基础性、 战略性、前瞻性的重大创新贡献。

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